Propagation of Fruit Trees
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PROPAGATION OF FRUIT TREES

By H. A. Cardinell and F. N. Hewetson

MICHIGAN STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
SECTION OF HORTICULTURE
EAST LANSING

The start of a two-year grafting program. Limbs on north half have been cleft-grafted and the south limbs left to prevent sunscald, to bear fruit and take up surplus vigor that might otherwise produce extra-long cion growth. Note the retention near each clefted stub of short feeding limbs that have been left to draw water and food material to the cions.

CONTENTS

	PAGE
Definition of Terms	6
Propagation in the Orchard	7
To Graft or Not to Graft	7
Collection, Selection and Storage of Cion Wood	7
Season for Grafting	10
Grafting Supplies and Equipment	11
Top Working	16
General Considerations	16
The Cleft-Graft	22
The Bark-Graft	29
The Inlay-Graft	30
The Tongue- or Whip-Graft	35
Budding	36
Subsequent Care of Grafts	38
Repair Grafting	41
General Considerations	41
Protection of Trees from Rodent Injury	42
Care of Wounds	42
The Bridge-Graft	44
The Approach-Graft	50
Propagation in the Nursery	53
Grafting Nut Trees	54
Index	55

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Propagation of Fruit Trees*

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In the early days it was quite common for orchards to consist entirely of seedlings, so that such an orchard would have as many varieties as there were trees. Among these trees were many that produced low yields of poor quality fruit and which were a liability rather than an asset to the grower. Today, through selection, breeding, and the use of suitable methods of propagation, a fruit grower can choose varieties of known performance which will enable him to produce high quality fruit that will find a ready market.

Even though the fruit grower buys his trees ready-made from a nursery, he is likely sooner or later to encounter contingencies which make a knowledge of plant propagation desirable or even essential. A few of the more important possibilities which may arise during the life of the orchard should therefore be mentioned. Because seedling fruit trees produce fruit of a variable nature, it is necessary to bud or graft them to varieties of known performance in order that the resultant trees will bear the desired variety of fruit. This phase of propagation is usually performed in a commercial nursery, and while nurserymen occasionally make mistakes during shipping and distributing to the trade, more often jobbers and dealers lose labels from bundled trees. Some of these trees may prove, on coming into bearing, to consist of varieties other than the labels indicated. On the other hand, however, growers sometimes make mistakes and order varieties which later prove undesirable. In both these cases it is necessary to rectify the mistake by changing the variety to the one desired by means of some form of top working. A change of variety may also be advisable when market conditions change, leaving the grower with an orchard of trees bearing fruit which cannot be sold advantageously, as has happened in parts of Michigan on a large scale with the Duchess apple. In still other cases, market demands may render desirable the growing of certain varieties such as Grimes, King, or Steele Red (Red Canada) which do best when grown on a hardier or more vigorous trunk. This involves a method of tree building known as double working and which may necessitate grafting the young tree in the orchard. Again, it may be necessary to introduce one or more pollinizer varieties into solid blocks of sterile varieties so as to assure satisfactory yields.

The first two editions of this bulletin were published under the title "Grafting in the Apple Orchard," by H. A. Cardinell and F. C. Bradford. Most of the observations cited in the present edition were made by F. C. Bradford and have been retained.

Finally, though the variety remains unchanged, repair work essential to keeping the tree in good condition may involve bridge or even approach grafting.

DEFINITION OF TERMS

STOCK signifies the root, tree, or portion of a tree into which the graft is set. Ordinarily it furnishes the root system of the completed tree, and it may furnish a portion of the top. In most cases, the stock is grown from seed, but under certain conditions it may be propagated vegetatively from stool beds, layers or cuttings.

CION denotes the bud or piece of twig grafted into the stock. From it grows a branch or a whole tree top which bears fruit according to its kind.

INTERSTOCK or INTERMEDIATE denotes the piece of trunk or the entire framework which is introduced into the tree between the stock and cion. It is chosen for its vegetative characteristics of vigor, hardiness, framework forming ability, and/or its disease resistance, and not for its fruiting characteristics.

CAMBIUM LAYER refers to a certain layer of living cells surrounding all woody portions of the tree. During the growing season these cells are constantly dividing, forming new cells; those produced on the inside form wood and those on the outside form the inner bark. Consequently the cambium layer is the source of all growth in the thickness of the woody stem and of most callus formation, particularly in older wood. It is the most distinctly live tissue in the stem, and its preservation is essential to further growth. Investigations in Massachusetts have shown this layer in young apple wood to be from six to ten cells only in thickness. Therefore the exact limits of this zone of growth can hardly be discerned with the unaided eye. Its location, however, can be recognized from the statement that peeling the bark from the tree while the bark is loose ("slipping") divides the cambium layer, part adhering to the bark and part to the wood. The paste-like substance that can be scraped at this time from the wood surface exposed by lifting the bark is composed in part of cambium-like cells.

GRAFTAGE may be defined as the operation of inserting a part of one plant (the cion) into or upon another (the stock) so that they will form a union and grow together. Graftage includes grafting and budding. In grafting, using that term in the more restricted sense, the cion consists of a piece of stem bearing one or more buds. Budding, on the other hand, refers to the use of a single bud with or without a piece of wood attached.

BUDSTICK signifies current season's growth from which single buds are to be removed for budding. From it may grow a branch or a whole tree top.

TOP WORKING refers to the practice of changing the top of a tree from one cion variety to another by some form of graftage.

DOUBLE WORKING refers to the practice of introducing an interstock into the tree by successive budding or grafting operations and hence is a definite tree building practice.

DOUBLE-WORKED TREES consist of stock, interstock and cion, each of which is chosen for special characteristics which enable it to make some definite contributions to the ultimate behavior of the completed tree.

PROPAGATION IN THE ORCHARD

TO GRAFT OR NOT TO GRAFT

Before undertaking any major tree grafting operation the owner should carefully consider whether it is more economical to replace the tree or perform the grafting operation. After surveying the cases of top-worked orchards in which the work was done after the trees were well into bearing, investigators found as many failures or near failures as there were complete successes. The same may be said of trees completely or extensively girdled wherein numerous long cions must be employed to repair the loss of trunk bark or where wound callus indicates that the injury occurred the previous year.

In general, the younger the tree the better will be the chance for successful recovery without seriously shortening the life of the tree (Fig. 1). However, in the case of very young trees, the replacement cost must be carefully weighed against the cost of bridge grafting the girdled tree.

The owner, therefore, is urged to consider the age and hardiness of the trees to be grafted as well as their vigor, and then decide whether the lost years of production or even of reduced production may be recovered within a reasonable length of time, usually 5 to 10 years in the case of major operations. Obviously, trees completely top-worked never catch up with the total lapsed production that a bearing tree would have given if its limbs had not been cut back for grafting. It resolves itself into the gamble, whether the new variety top can produce more net profit or satisfaction to its future owner than could the old variety; and in the case of girdled trees, whether the injured tree is worth the cost which repair work will involve.

COLLECTION, SELECTION, AND STORAGE OF CION WOOD

During the dormant season and preferably before pruning starts it is advisable for the grower to make a thorough survey of his orchard as regards the amount of grafting that he expects to do in the following spring. From this survey he can estimate the varieties, lengths and amounts of cion wood necessary for top working and repair grafting and can collect and

store the necessary material as soon as possible. Every spring there are frantic calls from growers for cions to repair trees injured by rabbits, mice, winter killing, fire blight and tools the previous season. These injuries are often not discovered until it is too late to collect suitable cion wood. The wise grower, therefore, will cut and store every winter, in addition to his

Fig. 1. One of thousands of fruit trees severely damaged by the outbreak of field mice in the winter of 1935-36. A knowledge of how to save such trees is one object of this publication.

calculated needs, an adequate amount of long cion wood for emergency repair grafting. A little such forethought will save many trees.

Cion wood should be selected from the most recent growth. For example, cions set in the spring of 1943 should be cut from wood grown in 1942. This can be distinguished readily from older wood by starting at the tip and proceeding backward to the first ring of scars encircling the twig (Fig. 2). This ring marks the position of the bud scales where growth for the year began. Behind it the bark differs markedly, and in vigorous trees the older wood has spurs instead of the simple buds that characterize the young wood. For the increase of cion wood of a new or rare variety, somewhat older wood may be used. Cions cut from three-year wood have grown in the College orchard, but the percentage of "take" is low, and older wood should not be used for commercial top working. An exception to this rule, applicable under special conditions in bridge grafting, is noted later.

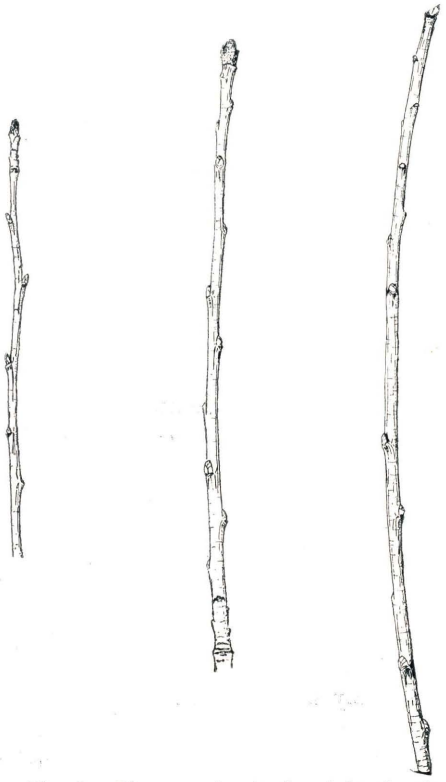

Fig. 2. Cion wood. At the right the tip is undesirable because of immaturity; the center twig is good except for being very close to the base. At the left is a twig of a type which often deceives the unobserving. The growth of the past season is confined to a very small portion near the tip; the rest is too old to make good cion wood. Note the way the buds stand out on this twig; these buds are not laterals, like those on the other twigs, but are on very small spurs.

Twigs which have made a growth of from one to two feet in the last season ordinarily furnish the best cion wood. Cions the thickness of a common lead pencil are preferable. Very careful investigation in Illinois has shown that the position of the twig on the tree is of no importance. Water sprouts make good cion wood—provided they do not originate below the graft. Furthermore, because they remain dormant longer, when cions are cut late, the water sprouts make the best cion wood. The only objection to them lies in the fact that they are likely to be immature and if the cions are cut in the spring this wood may have been damaged somewhat by cold weather. Very vigorous growths on the ends of branches are open to the same objection. Twigs showing discoloration in the pith or wood should be discarded or cut back to sound wood.

Immature tips should be discarded, not only because of their tendency to winter injury, but because they are likely to have poorly developed buds, and to lack stored food materials for forming callus tissue and starting growth. The bases of very vigorous twigs also may be poorly suited to use as cions. Other things being equal, if a long twig be divided in imagination into four sections of equal length, the best cion wood will be found in the two inner quarters. Twigs showing many aphid eggs should be cleaned or discarded, preferably the latter.

Cions may be cut at any time while they are dormant. If taken in the fall they will be safe from winter injury.

The proper care and storage of cions after they have been collected is extremely important. In order to keep them alive but dormant, they must be stored in a cool place and suitably packed so as not to dry out. A simple way to store cion wood is to wrap the cions in cloth or heavy paper and then bury them horizontally in a well-drained spot, preferably on the north side of a building. A depth of two feet will generally be sufficient to protect them from freezing and drying out. With the increase in farm cold storage, many growers may wish to store their cion wood in these buildings. However, certain precautions are necessary. The cions should be wrapped in moist but not too wet burlap or sacking and this again wrapped in dry, heavy paper. The burlap should be examined periodically and dampened when necessary. If the burlap is too wet it may cause the growth of mold, and if allowed to become too dry the cions will dry out. In either event cions may fail to grow.

Cions must be dormant when they are set. Dormant cions will grow if set into stocks which have advanced to the blossoming stage, or sometimes even farther, but the percentage of "take" decreases very rapidly with the advancement of the buds on the cion. Since, for reasons to be explained later, the failure of any considerable portion of cions to "take" may seriously impair the ultimate success of those which do, grafting with cions whose buds are opening should not be attempted, unless under exceptional conditions. Such a condition might be that of desiring a temporary means of preserving and increasing a supply of rare cion wood which would be lost otherwise. Such a course is justifiable and may even be measurably successful, particularly if the grafts are shaded for a time with paper sacks or coated with paraffin, but if dormant cions are lacking, commercial top working should be postponed. Sometimes, after all wood suitable for cions in the orchard has started growth, it is still possible to obtain a limited supply from trees in a nursery storage shed or even from young trees in the orchard since the start of their growth is often many days later than older trees.

SEASON FOR GRAFTING

Grafting for top working in the apple orchard can be done to best advantage at about the time when the buds on the trees are beginning to swell.

The cleft- and the tongue- (whip-) grafts, used in top working, may be made while stock and cion are still dormant or they may be made with dormant cions on trees which have advanced to blossoming, though this last time is rather late for best results. The period just before the bark begins to slip offers some advantage in cleft grafting because at this time the bark and the wood split at the same point, while when the bark begins to slip it sometimes splits a little to one side of the cleft in the wood, and the proper placing of the cion becomes difficult.

Work done in Ohio shows that over a period extending from November until July the highest percentage of successful grafts was obtained in May, although grafts made in April, June, and July were nearly as successful. Cions for the later graftings were kept dormant by cold storage until ready for use.

Bark grafting, sometimes used in top working trees, is done after the bark has begun to slip.

Bridge grafting may be done much more easily and with a higher proportion of "takes" after the bark has begun to slip. Any of the methods used in adjusting the cion to the tree for bridge grafting involves the raising of more or less of the bark, and to do this before the bark slips is extremely difficult.

GRAFTING SUPPLIES AND EQUIPMENT

The tools and equipment needed in grafting and budding can usually be purchased from a hardware store, seed store or nursery supply company. These include grafting tools, mallets, knives, sharpening stone, pruning saw and shears, a suitable hammer, a supply of No. 18 nails and some type of grafting wax or compound. Also suitable containers for soft or hard wax, unless asphalt water emulsion is used. If hard wax is used, some type of heater will be required.

The grafting tool, or clefter as it is sometimes called, if not obtainable through the cited channels, can easily be made by a blacksmith or in the farm workshop according to illustrations in this bulletin.

The purpose of the concave outline of the cutting edge is to insure cutting of the bark, particularly in the upper part, before the wood is split, thus in some measure avoiding tearing of the bark. Besides this, it will aid in obtaining a uniform cut in wood of twisted grain. If one of these tools is to be made primarily for a single job, where there is considerable uniformity in the size of the stubs to be grafted, the radius of curvature, ("degree of convexity") of the cutting edge can be made to fit the size of the stubs. The smaller the stubs, the smaller should be this radius (the greater the "degree of convexity"), as shown in Fig. 4. The types commonly sold have a uniform curvature in the cutting edge and for this reason cannot be equally suited to stubs of all sizes. If the tool fits the large stub, it splits the smaller with very little cutting; if it fits the small stub, it crushes the edges of the

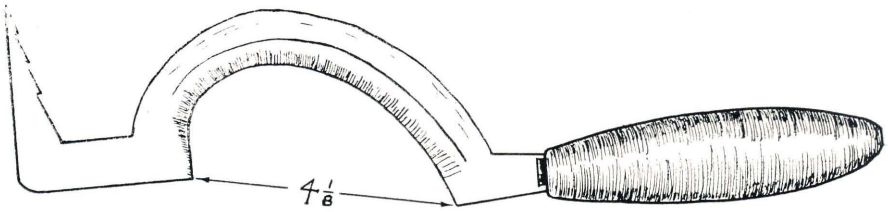

Fig. 3. A grafting tool for stocks of various sizes. The wedge should set out well from the cutting portion. Note the varying curvature of the cutting edge. Lower the handle for small stock; raise handle for large stock.

larger before splitting begins. No edge has been devised within the bounds of practicability to fit all stubs equally well, but an approach to an edge of this kind can be made with a curve of more or less steadily increasing radius (Fig. 3). If one uses such a tool as shown in this drawing, holding the handle upward adjusts the edge to the larger stubs; holding the handle down adjusts it to the smaller, and the intermediate sizes can be reached fairly well by holding the handle level.

A hammer may be substituted for the mallet. Knives should be of good steel and be kept sharp, because a dull knife can spoil many a graft. A speed saw is useful when working on the larger trees. Recent work at Michigan State College has proved the value of an asphalt grafting compound as a possible substitute for the hard or brush wax previously recommended. Rubber budding strips 3/16 x 4 inches are useful for budding but are not now available, so string and raffia must be used instead. A simple home-made wax heater is illustrated in Fig. 5. Such heaters may also be purchased from dealers. A modified carpenter's apron to hold equipment and cions may be a useful accessory.

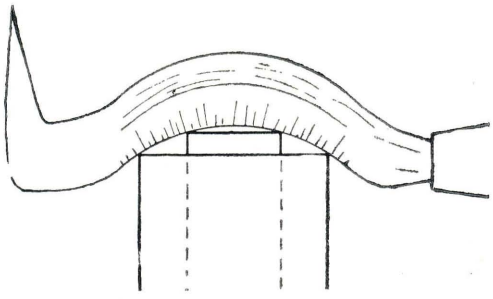

Fig. 4. Illustrating the reason for the varying curvature of the cutting edge shown in Fig. 3. Uniform curvature does not fit stocks of various sizes.

The best brush for applying graft coatings is about an inch wide. The brush should not be allowed to rest deep in hot wax for any length of time; else, the heat will melt the glue in which the bristles are set and they will pull out. This can be prevented by driving a small nail in the handle of the brush and bending it over as a hook for hanging the brush to the rim of the pot, taking due care that it is allowed to hang with the bristles just above the wax. This will bring the nail high enough on the handle so as not to interfere with manipulation of the brush. The use of cold asphalt

grafting compound of the water emulsion type avoids the need for any heating equipment.

The kinds of waxes that have been used in grafting at some time or other are very numerous and diverse, ranging from a mixture of chopped straw and blue clay to rather complicated kinds for special purposes. Occasionally, good results have been reported from paraffin, from ordinary fly paper—though these have sometimes proved injurious—and even from adhesive tape. The fact that such diverse materials are occasionally successful indicates that they meet certain fundamental requirements in some degree; the fact that they are not uniformly successful indicates deficiencies that are of no importance at some times but fatal at others.

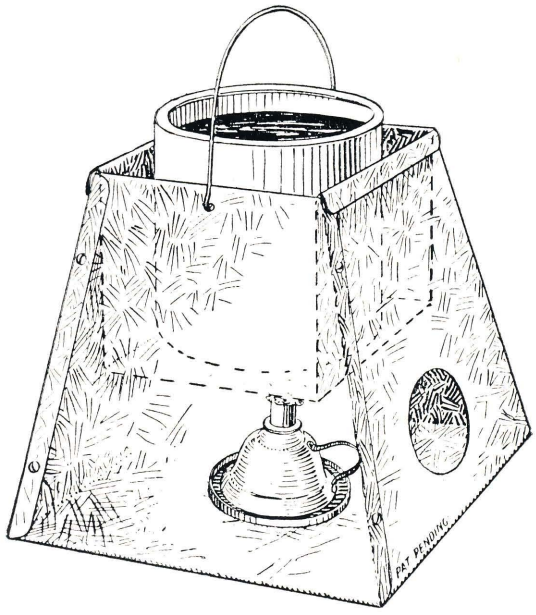

Fig. 5. Heater for hard or brush wax.

The ideal grafting wax would have at least these qualifications: (1) it would exclude air and fungi and retain the moisture of the wood; (2) it would contain no material that will injure live tissue in the strength at which it is used; (3) it would not crack in cold weather; (4) it would not run in hot weather; (5) it would be semi-permanent in possession of its various virtues; (6) it would have more or less elasticity, to accommodate itself to changes in dimension of stock and cion consequent upon growth; (7) it would have sufficient body to fill cracks; and (8) it would also be relatively cheap and easy to handle.

No wax yet devised meets all these requirements perfectly, but several meet them well enough for practical purposes under the conditions to which they are ordinarily exposed.

Most of the older waxes require heating before they can be used; some become pliable at the temperature of the hands and are called hand waxes. Others, with a higher melting point, are heated and applied with a brush while warm; these are called brush or hard waxes. In the liquid waxes some solvent, usually alcohol, is used; the wax is applied cold, and the evaporation of the alcohol leaves a solid residue.

Hand waxes are expensive to make and unpleasant to use, especially in cold weather, and are also very wasteful of material. For those reasons their use is not recommended. Where a brush wax is desired, the following formula makes a suitable compound: 5 pounds resin, 1 pound beeswax, ½ pound lampblack or powdered (not ground) charcoal, and ¼ pint raw linseed oil. This is in a sense a basic formula, and may at times be varied somewhat to suit special conditions. For example, for grafting very late in the spring, with warm weather, the proportion of resin may be increased, while for grafting very early in the season with cold weather still to be expected, the proportion of linseed oil may be increased. To make this wax, the resin is melted, beeswax added and melted, linseed oil added, the mixture removed from the fire and the lampblack stirred in a little at a time, to avoid boiling over. This mixture, with the linseed oil added, appears to be even more inflammable than the hand wax mixtures and should be treated accordingly.

As soon as the cooking is completed the wax may be cooled somewhat and used at once. For operations of any extent, however, it is best to prepare the supply in advance. The hot wax may be poured into shallow pans, to the depth of about an inch and allowed to cool. Thorough cooling will take some time; when it has occurred a sharp blow on the bottom of the pan will loosen the wax which can then be broken into small lumps. These small lumps are convenient when a small heating pot is used.

Occasionally, when the wax is applied very hot, there is some injury to live bark, particularly on the cions, where the bark is thin and tender. This trouble is rarely encountered in practice, where the ordinary types of heaters are used; it is more likely to occur when the wax is heated over rather large fires and applied immediately upon removal. If the wax made by the foregoing formula does not set at once but is inclined to run when applied, it is probably too hot for safe use.

This brush wax retains its various good qualities longer than any of the hand waxes. It is applied more easily and more rapidly, leaves fewer air holes and though it is harder it seems less likely to crack. In addition, rather less of it is required for a given amount of work and it is, pound for pound, cheaper. Beeswax is the expensive ingredient in any wax, costing ordinarily from six to ten times as much per pound as the resin. This brush wax requires a pound more of resin and a pound less of beeswax for the six pounds of resin and beeswax combined that constitute the bases of the respective waxes.

The lampblack serves a two-fold purpose. Without it the wax is very sticky, stringing out in long threads with every stroke of the brush. Its black color helps in heat absorption, making the wax pliable though it does not run. This pliability is advantageous in that the expansion of the growing cions is less likely to force the wax loose in large masses; in some cases

minute cracks in the wax have been known to disappear after a bright warm day, the wax becoming soft enough to unite again.

Various attempts have been made to devise a cheap substitute for beeswax. Paraffin is sometimes recommended. Though success undoubtedly attends its use alone under favorable conditions, it cannot be recommended for general use because of its tendency to crack. During one season in the College Orchard, it has given fairly satisfactory results as a substitute for beeswax in the brush wax. The wax containing paraffin was full of bubbles and seemed rather thin, yet the growth of the grafts to which it was applied was entirely satisfactory. It must, however, be observed under more varied conditions before it can be definitely recommended or condemned.

Extensive trials by the senior author of a number of coatings other than the standard brush wax have furnished information concerning many proprietary grafting compounds. Out of these trials has emerged an asphalt grafting compound which has given consistently good results and is now recommended by the College. This wax substitute is an asphalt water emulsion. It is sold in containers of various sizes and has only to be diluted with cold water or alcohol to the consistency of a thick paint for immediate use. It is best applied cold with a brush in the usual way. When left uncovered for many hours, cold water should be poured on top of the asphalt emulsion and poured off when work is resumed. Stock carried over winter should have water standing to a depth of several inches if not tightly sealed and to a depth of one inch if sealed and stored in a warm place. If stored where water would freeze, enough "radiator-type" alcohol should be stirred into the asphalt emulsion to prevent the emulsion from breaking down and a little alcohol poured on top of the mass of asphalt before tightly sealing. This precaution will assure a product ready for use when needed. If it is necessary to apply this material in very cold weather, enough of the paste-like compound for a half-day's work should be taken out of the original container and diluted with radiator-type alcohol. This should be done in a warm place so as to safeguard against breaking down the original emulsion, which may be injured at temperatures below 40° F., until alcohol is thoroughly incorporated with it.

Trees girdled by rodents or by any other means usually "bleed" sap in the spring and very few safe materials will adhere to such a slippery, moist surface. Asphalt water emulsions adhere well to such surfaces and should be applied as soon as the injury is discovered in order to reduce water loss and checking of the wood as it dries. These recommended asphalt water emulsions, therefore, may be used as a wound dressing as well as a grafting compound (see Fig. 6).

Of the various asphalt water emulsions tested, "Flintkote Static" and "Foster's I.B.M." (an asphalt dispersion) gave equally good results. Unfortunately, some of these safe asphalt emulsions are marketed under some

Fig. 6. The photograph on the left shows how poorly a heated brush wax adheres to the moist surface of a rodent injured trunk as compared with asphalt water emulsion shown on the right.

other trade name. It is therefore advisable to ascertain the origin of the material being sold, either by finding out from the dealer or by writing to this Station. There are many grafting compounds on the market which have proved very injurious to trees and which have either killed or dwarfed cion growth when used to cover cions and grafting wounds. The grower is advised to avoid using grafting compounds not recommended by the Experiment Station and to use only those materials which have been thoroughly tested.

TOP WORKING

GENERAL CONSIDERATIONS:

The primary object in top working a tree is to change the variety of the fruit borne thereon. The success of this change is dependent upon several details. First, the union must be sound; second, the limbs to be grafted

must be properly selected; third, the tree must not be exposed to sunscald during the process; fourth, the new variety must be compatible with the variety on which it is worked.

Soundness of union depends largely on soundness of stock, care in the actual making of the graft and subsequent treatment of the resulting cion growth, as discussed later under the "Cleft-graft".

In selecting the limb to be grafted, due consideration must be given to the diameter, position and number of limbs to be grafted. When the cleft-graft is used, the upright limb having a diameter of 1 to 2 inches will give the best results.

Cions should never be set where they will be heavily shaded because their growth will be meager. As a matter of economy, they should be set only in places where they will have a chance to develop into limbs of considerable size. Small horizontal limbs close to the ground, where they are overshadowed by other better limbs, are often very tempting, because of the ease with which they can be grafted, but they should be avoided. Branches anywhere which, because of their position, can never become large, are not likely to be worth the trouble of working over. Unless it be for early fruiting of some new variety or to provide for cross-pollination at the earliest season possible, grafts should not be set near the tips of branches which have already extended as far as they are likely to grow. (See Fig. 7, and compare with picture on the cover.)

The limbs selected for grafting must also be well spaced around the tree to furnish a well balanced framework for the rebuilt tree. An illustration of well selected branches is shown on the cover. The number of limbs selected for grafting should be as few as is consistent with good results, partly to save time, but also because it is desirable to reduce the number of new scaffold limbs and permit the new variety to make its own framework.

Top working of large trees, though possible, is likely to be unprofitable. The main limbs are so large in their lower portions that grafts cannot be set here with much likelihood of good unions resulting. The only wood of proper size for grafting in these trees is very high and so far out on the limbs that only a small amount of fruiting wood can develop from each cion. So many branches must be grafted if the top working is done here that the operation becomes very expensive. Furthermore, when grafts are set so high in the branches there is constant trouble from sprouts emerging along the branches below the graft; these must either be grafted in their turn or removed. Grafting of smaller branches low on the limbs and the subsequent cutting of the old limbs back to these branches, a treatment sometimes attempted, are likely to cause decay starting at the point of amputation and the final breakdown of the whole branch with the first heavy load of fruit on the new growth. In case the fruit of the old tree is utterly worthless there is, of course, little but the labor to lose in attempting a renovation of

Fig. 7. The experienced fruit grower will recognize at once that this tree was too large to be top-worked by cleft grafting. In order to find limbs of the 2-inch diameter size it was necessary to set the cions 8 to 12 feet from the ground. The economic future of such a tree is seldom a success.

this sort. Even then, however, there is at least an even chance that more satisfactory results will be obtained by removing the old tree wholly and planting a new tree.

Low fruiting wood, protection against sunscald, and the setting of the minimum number of grafts are more or less interdependent and should all receive consideration when top working is undertaken. Of the three, perhaps protection against sunscald is the most important, as it is concerned to a high degree with the soundness of the tree. It is in itself of less consequence than the disorders which are likely, or, in a majority of cases,

sure to follow it. Among these are flat head borers, which make still easier the entrance of wood-destroying fungi, producing eventually a hollow heart and finally a broken limb. Even without the borers these fungi gain entrance through the sunscald lesions. An injured area of this sort is almost certain to be invaded sooner or later by the black-rot fungus which will in time girdle the limb.

Sunscald is likely to occur when any considerable portion of a smooth-barked branch is exposed directly to the sun, particularly from noon to 2 or 3 o'clock. The more nearly at right angles the sun's rays strike at this time the greater the likelihood of damage. The larger limbs with smooth bark are, despite their thicker bark, as likely to suffer as the smaller ones, because the greater curvature on the surface of the smaller limbs increases the reflection of heat and thereby diminishes the absorption. Moderately large limbs leaning to the north and northeast are most subject to injury.

If the whole tree is top-worked at once, much or most of the small wood which bears the foliage is removed and the sun's rays admitted freely to the bark of the northward-leaning branches. Under those conditions, sunscald is likely to develop. Its onset is sometimes slow under Michigan conditions. The first year's scorching may be confined to the outer bark, the next year's extending somewhat deeper and so on. There are, however, numerous examples of very bad cases developing in one year.

As a safeguard against sunscald, then, top working a tree should be spread over two years. In the first spring, the work should begin on the northeast side and embrace about half of the tree. The stubs grafted at this time are shaded by the branches still untouched, and they are thus protected against injury. During the first summer, water sprouts generally grow out in considerable numbers on the grafted limbs. Of these, those that are so placed as to shade the limbs should be retained. If they are pinched back when 6 or 8 inches long, they will branch and increase the shade. In any case, they can be kept small by cutting back in the spring. The remainder should be removed during the summer or in the following spring; those utilized for their shade can generally be removed in the third spring.

In the spring of the second year, the top working may be completed. The water sprouts and the growth from the cions should provide, from this time on, sufficient shade for the limbs on the north side. Therefore, grafting the remaining limbs may be done with no danger of sunscald on those first grafted. Since these remaining limbs have a more or less southerly inclination, they receive the rays of the sun during the warmest weather at a very acute angle, so that more heat is reflected and less absorbed. Not only is this true, but in addition, any given area on the limbs leaning southward receives less heat than an equal area on a limb leaning toward the north.

A skillful operator can distribute grafts in various parts of the tree, in-

stead of working from side to side, and by setting the cions in shaded places he can do this without great danger from sunscald. However, if only one branch on a limb is grafted, the growth of the cions and water sprouts is likely to be much less than it is when several branches on a limb are grafted at one time. When, therefore, the second year's grafting removes the shading limbs, those that were worked over in the previous year are likely to suffer.

The experienced tree grafter can so spot grafts in key positions as to complete in one year all the grafting necessary to remake the tree without unduly exposing it to sunscald or excessive growth of cions; others should, for a time, follow the two-year plan.

A method of top working has recently been developed at Michigan State College by Bradford and Cardinell, known as the "Inlay"-bark-graft. This method is especially designed for reworking trees too large for the conventional cleft-graft, but which are still in a good healthy vigorous condition and give promise of many more years of useful service. This method is described in a later section of this bulletin.

As a matter of record, it should, perhaps, be stated here that the notion, revived about once in each decade, of cutting off an old tree and setting 15 or 20 grafts around the stump is usually founded on enthusiastic observation of the first year's growth. The debacle generally occurring, at the latest, about the seventh year, from the breaking out of the grafts, rarely receives mention. The expansion of the grafts extends, naturally, along the cambium of the stumps, and as the curvature of this is slight in large stumps the union is almost wholly in one plane so that some additional strain such as weight of crop, accumulation of ice or a strong wind at right angles to this plane is, sooner or later, going to snap the graft or pull it out at this point. If supporting the graft by a stake is attempted, there is still no known means of forcing the callus to grow around and over the stump.

The matter of compatibility between the old framework and the variety grafted thereon, as well as the varietal characteristics of the original tree, should be given some consideration in top working. In general, most apple varieties may be satisfactorily grafted on one another, the main limitation being the matter of relative vigor. Thus it may be unwise to graft over weak-growing varieties such as Wagener, Pewaukee and Duchess to strong-growing varieties such as Northern Spy and Rhode Island Greening. If this is done, the coarse-growing cions develop into limbs too heavy for the crotches of the weak-growing stocks and breaking may occur, not necessarily at the graft union, but more often at the crotches. Such a union is shown in Fig. 8.

Pear varieties may be grafted on one another without fear of any incompatibilities developing. However, because of the susceptibility of this fruit to fire blight, consideration must be given to this matter before under-

Fig. 8. Grafting a strong growing variety on a weak growing variety, (as Rhode Island Greening on Duchess) may throw undue weight on small crotches, causing breakage, not at the unions, but at the crotches.

taking any extensive operation. Further discussion of this problem as it relates to grafting will be taken up under the subject of interstocks.

Peach varieties are compatible with one another, but certain modifications are necessary for top working peach trees. Such trees are generally only top-worked when the variety has been proved untrue to name or in the unusual case when a pollinizer variety is needed. In these cases top working is confined to young trees which have an abundance of small pencil-sized branches close to the center of the tree and fairly close to the ground. These branches may be top-worked by budding in the late summer and cut back the following spring.

Top working of cherries and plums is not recommended, owing to the uncertainty of success with these fruits.

Double-worked trees are produced by first budding the variety which is to form the interstock, onto the stock. The interstock is then allowed to grow

for a year or more, when the variety which is to form the top (the cion) is finally budded onto the main stem or branches of the interstock.

Certain varieties grow best when double-worked into hardier or stronger growing trees. This matter as it relates to hardiness is treated at some length in Michigan Special Bulletin 149, *"Eighty Winters in Michigan Orchards".** According to the findings in this publication, Grimes Golden, King, Baldwin, Hubbardston, Golden Delicious, and probably Rhode Island Greening should be grown as double-worked trees. Suitable stocks to form the trunk and in some cases also the framework of the tree seem, from available evidence, to include Tolman Sweet, Snow, Virginia Crab, and Wolf River.

Grimes is now offered already double-worked by several nurseries. As these trees are sold, they have been grafted in the main trunk about a foot above the ground so that the whole framework is Grimes. This arrangement will, perhaps, be satisfactory with Grimes, since the injury in this variety is chiefly at the collar, but with the others named as tender, injury in the crotches is almost as common as that in the collar. For this reason it will be safer to let the hardy stocks grow for a time in the orchard and form the main limbs. These may be grafted in the spring of the third or fourth year after planting, or at this age budding would be practicable. Double-working of Steele Red (Red Canada) is done, not because of its lack of hardiness, but because it is a poor grower; in this case, too, the framework should be formed from a sturdier variety. Northern Spy has been favored as an interstock because of its vigorous growth, but cannot be recommended for this purpose because it is not perfectly hardy; if it is grafted in the limbs, its acute-angled crotches offer difficulties. Recent work has shown the desirability of using Virginia Crab as an interstock for Steele Red trees.

THE CLEFT-GRAFT:

The cleft-graft is made by inserting the cion into a split in a stub left upon sawing off a branch, or, sometimes in small trees, the main trunk.

Discrimination in selecting the points where the limbs are cut will be justified by the results. For reasons which will appear presently, grafting of limbs at points where they exceed 2 inches in diameter should not be attempted, and cleft-grafts set in limbs of diameter less than an inch will require special attention. Selection of points where the wood is straight-grained and free from large knots or scars for 6 inches below the cut will insure a straight and uniform cleft and thus help materially in fitting the cion. Furthermore, selection of these points should be made with the reconstructed tree in mind. Of this, too, more later.

The cut should be made square. This is not of particular importance so far as concerns the "take" of the cions, but it favors complete healing by reducing the diameter of the wound as compared with a sloping cut.

**This publication is out of print but may be available in public libraries and in the library of most public and private schools.*

Furthermore, it permits more latitude in the direction in which the cleft is made. Some operators smooth the cut with a knife; others, using a saw with fine teeth and little set, make no further attempt at smoothing. Smoothing the cut surface makes the locating of the cambium zone easier and helps beginners to set cions more exactly. In most cases, however, there is little discernible difference in the results.

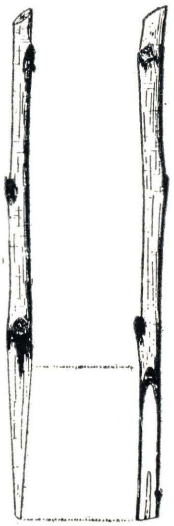

Fig. 9. Cions trimmed for cleft-graft.

Cions for top working are cut to two or three buds. A two-bud cion is less likely to be forced out either by birds or winds than the longer cion, owing to its shorter length. The writers favor a two-bud cion, but of greater importance than the length of the cion, however, is its diameter. Pencil size (approximately 5/16 of an inch) should be used as much as possible. Thinner cions do not have enough stored food and often shrivel and die before a union has been made. They are trimmed about one-fourth inch above the top bud, with the cut sloping somewhat down to the side opposite this bud. Terminal buds may be flower buds and should be discarded. The lower cut should be made one and one-half inches or more below the lowest of the three buds.

The bevel cuts shown in Fig. 9 should be so made as to insure the greatest possible cambial contact. This increases the chance of union and also increases the rate of growth of the cion. It is not necessary, and in fact it is often distinctly undesirable, that the cion be trimmed to a pointed wedge. Fig. 10 shows that this sort of wedge often reduces the area of possible contact and, furthermore, since the contact surface is reduced the cion is held less securely and is likely to "rock" at a slight touch or to blow over later when it has grown enough to present considerable surface to the wind. Extremely long cuts and drawing the wedge out to a very thin point have no special advantage, except that of a possible greater cambial contact. Actually, however, in many cases this possibility fails of realization. Minor irregularities in cion or in stub make very long contacts difficult to establish. In

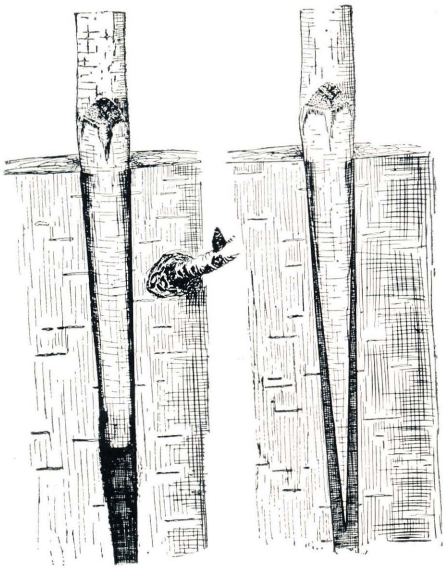

Fig. 10. Drawing the bevel out to a point (right-hand figure) is likely to diminish the extent of the contact surfaces and to produce a "rocking" cion.

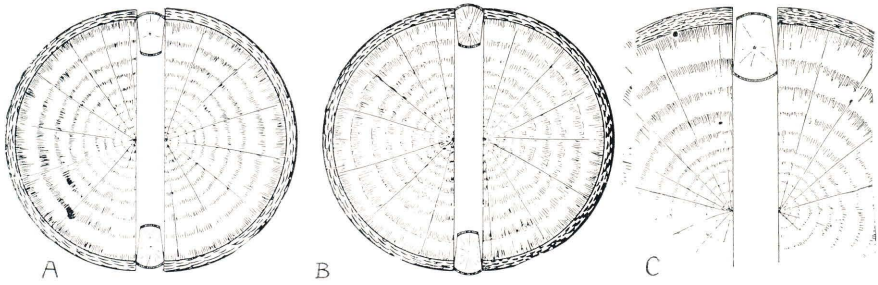

Fig. 11. Why some grafts fail. Lack of cambial contact between stock and cion can come about in more than one way. A, shows grafts properly made and properly set; B, shows failure of contact through setting the surfaces flush; C, shows failure through undue thickness of inner part of cion.

addition, the thinness of the wedge exposes the pith on the bevel surfaces and cuts the woody cylinder surrounding it into two separate pieces which turn or crush under the compression of the stump when the grafting wedge is removed. This is particularly important in small cions. Whatever happens, however, the wedge must not be so thick as to prevent the top of the stub from clasping it. Contact all along the cut is desirable, but contact at the top of the cut and of the stub is essential to a good union.

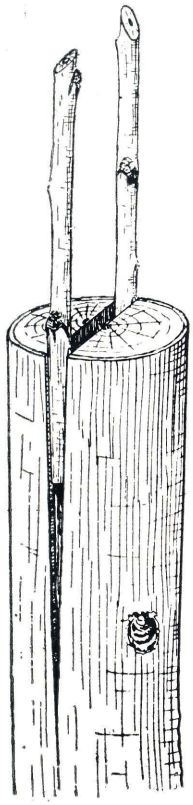

Fig. 12. Cleft-graft complete except for waxing. Note correct position of lowest bud on the cion.

The upper edge of the bevel cut should be at, or slightly below the level of the lowest bud. Stored food reserves are more abundant here and callus formation, essential to the graft union, starts here first and is more abundant.

The "outside" of the cion should be thicker than the "inside". This insures contact between the stock and the cion at the region of the cambium (Fig. 11). If this precaution is not taken, a slight accidental unevenness may prevent the closing of the stock sufficiently to bring the outer edge in contact with the cion.

The lowest bud should be on the outside (Fig. 12). This insures placing the zone of richest callus formation at the point where cambial contact can be obtained with greatest certainty and where the union between stock and cion is of greatest importance to the subsequent healing of the stub. Furthermore, in many cases, from this bud develops a shoot which can be developed into an important part of the new framework (Figs. 13 and 14). If this bud faces in any other direction the new shoot must grow out across the stub and its subsequent expansion with increasing age will crowd it against the stub with ultimate danger to the graft. In addition, this young shoot

Fig. 13. An excellent example showing an auspicious start of well-placed cions on a well-chosen limb. Note the temporary retention of nurse shoots close to the cions and the perfect sealing of the union. (Photograph taken in Michigan and used by permission of the U. S. Department of Agriculture—No. S6676C.)

stimulates wood formation below it, and this should be on the outside of the cion where it increases the strength of the graft union rather than on the inside where it makes only callus, which tends to wedge the sides of the stock farther apart.

The bevel cuts should be continuous and uniform. Otherwise, cambial contact will be much reduced and the cion less securely anchored (Figs. 15

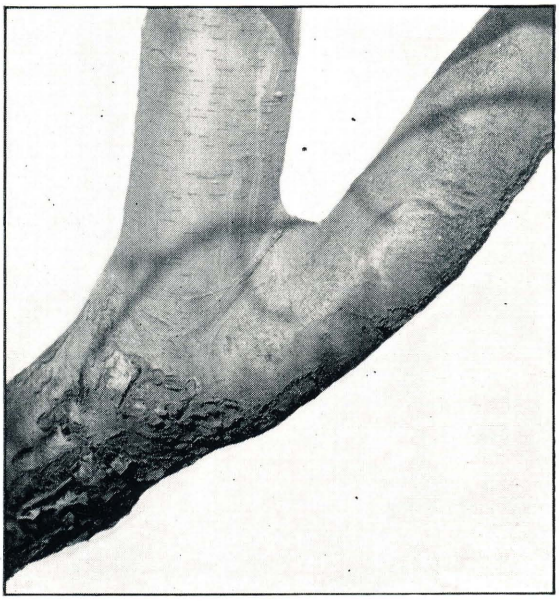

Fig. 14. An old graft. The basal bud has made a strong side branch, with a strong crotch. Contrast with Fig. 27.

and 16). The surest means of obtaining a uniform cut is to use a knife with a rigid and very sharp thin blade. Experienced operators generally grasp the cion in the left hand, holding it horizontal, with the tip under the thumb and resting on the first two fingers, and with the lowest bud uppermost. With the right hand holding the knife almost vertical but with the tip pointing a little to the right, the operator makes the first cut, starting beside the lowest bud and proceeding to the end with one shearing cut. The cion is then rotated so that the basal bud moves 90 degrees to the right and down; the left hand remains in the same position and the cion is rolled between the thumb and forefinger. The right hand assumes a horizontal position, with the back of the hand up, the knife blade pointed to the left and very slightly down, and the thumb below the cion. The second cut is made from this position. In each case the cut is made by drawing the knife toward the operator.

The cleft stub is now wedged apart far enough to admit the cions. In default of a better tool a screw driver may be used, inserting the blade into the fissure and then turning it. It is more convenient and satisfactory, however, to use a wedge attached to the tool used for the splitting. A smooth wedge will sometimes give trouble by slipping out. This can be prevented by a few ridges pointing backward on the wedge; these should be on one side only, else the wedge cannot be freed readily after the cions are set.

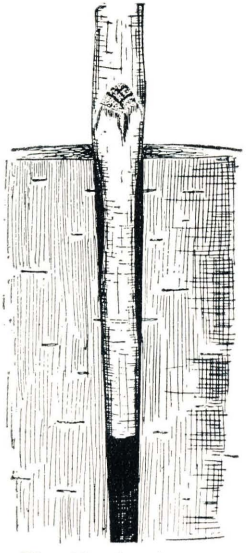

Fig. 15. Another cause of failure—irregular bevel, generally the result of poor edge on knife or failure to employ a draw cut. The hand should be held rigid and the arm muscles used in moving the knife.

The cion should be inserted so that its cambium layer is practically continuous with that of the stock. In any case, contact at the top of the stub is essential to good union, and contact along the rest of the cion favors better growth. Microscopic examination of successful grafts has shown that absolute continuity is not essential to a "take," but contact so far as the unassisted eye can tell is desirable. Failure to obtain this relative continuity in many cases results from setting the cion with its surface flush with that of the stock, disregarding the difference in thickness of the bark on the stock and that on the cion (see Fig. 11).

Sometimes cions are tilted somewhat, supposedly to insure cambial contact since the layers must cross at some point. Unless the bevels have been cut perfectly, this practice is dangerous since the crossing may occur at a point where there is no contact. Furthermore, tilting the cions almost inevitably leads to failure to obtain contact at the top of the stub. This failure makes the stub, like any projecting stub left in pruning, very slow to heal over. As the cion grows, its woody tissues, instead of flowing readily over the stub, accumulate at its side in a large knurl composed of fibers changing direction very rapidly and in aggravated cases this has led after several years to breakage of the cion, not at the union, but along the line of greatest bending of the woody tissue. This condition is, perhaps, worse when the cion is of a variety making grosser growth than the stock, but the danger is so great that tilting of the cions cannot be recommended in any case.

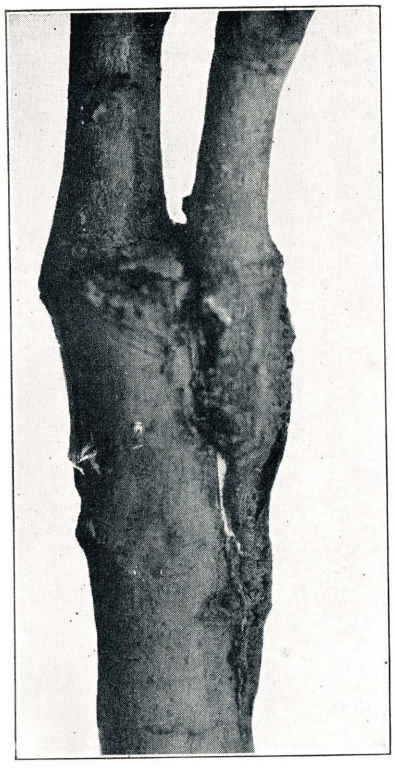

Fig. 16. The cion feeds the stock. The cion on the right made contact on its right and none on its left. Note the death of tissue in the stock at this point and along the cut edge of the stump.

The cion should be set so that the tops of the bevel cuts are level with the top of the stock in which it is set. Deeper setting would prevent the growth of callus from the stub and consequently delay, if it did not actually prevent, the healing of the union. Furthermore, expansion of the cion will tend to spread the halves of the stub farther apart (Fig. 17). Setting the cion somewhat higher, so that some of the cut surface projects above the stub, is less injurious in its effects provided these exposed surfaces are covered with grafting wax. If the stock

has been split too deep the cion should still be placed at the proper level and contact insured by drawing the split portions of the stock together with a thick cord or a strip of cloth tied about the stock close to the top. Even if this does cause some girdling, the tie should not be removed during the first season. The girdling will not be injurious, and with the tie removed the growth on the cion would be likely to spread the stub.

Two cions should be set in each stub, and both should be allowed to grow for a time. Generally, one of them must be removed sooner or later (see under "Subsequent Care of Grafts") but for a time both are needed to insure rapid healing of the stub. If a stub larger than two inches in diameter is to be grafted (though this is not recommended) two parallel clefts may be made, extending on either side of the center and two cions set in each cleft, making four for the stump.

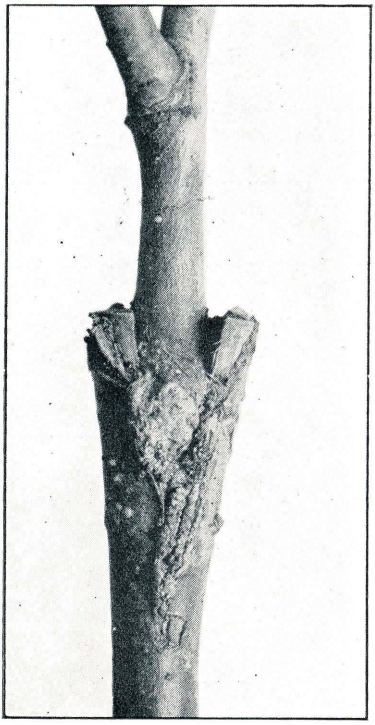

Fig. 17. Stock too small for easy use of the cleft-graft. Union made and growth proceeding, but cion set too deep to permit ready healing of stock.

All cut surfaces should be sealed with some form of grafting wax. For this purpose the asphalt emulsion grafting compound discussed under "Grafting Supplies" is recommended. Waxing is sometimes said to be for the purpose of keeping the moisture out. Actually the purpose is to keep moisture in. Some little care is necessary to avoid leaving minute air holes close to the cion, particularly in the part above the stub. Wax should extend down on two sides of the stub, closing in the clefts and for an inch or so beyond any visible cleft.

Waxing not only serves to retain moisture, but it may also prevent infection by wood-destroying fungi. This is doubly important in case either stock or cion has "black-heart," a form of winter injury, which makes it much more liable to fungous invasion. Cion wood in particular is sometimes slightly affected, not sufficiently to interfere with vigorous growth, but enough to predispose it to infection. Consequently, as a precautionary measure, cut ends should be waxed.

The most common causes of failure of cions to grow in the cleft graft, as in others, are (1) uneven edges on cion; (2) failure to obtain proper cambial contact; (3) imperfect waxing; (4) lack of dormancy in the cions; (5) cions too thin; and (6) fire blight bacteria which may infect the union.

THE BARK-GRAFT:

The bark-graft is described here because it is preferred by some operators to the cleft-graft in view of the ease of obtaining a "take" and because it does not involve splitting the stub. This last feature is said to favor more rapid healing and so permit the grafting of stubs too large for splitting.

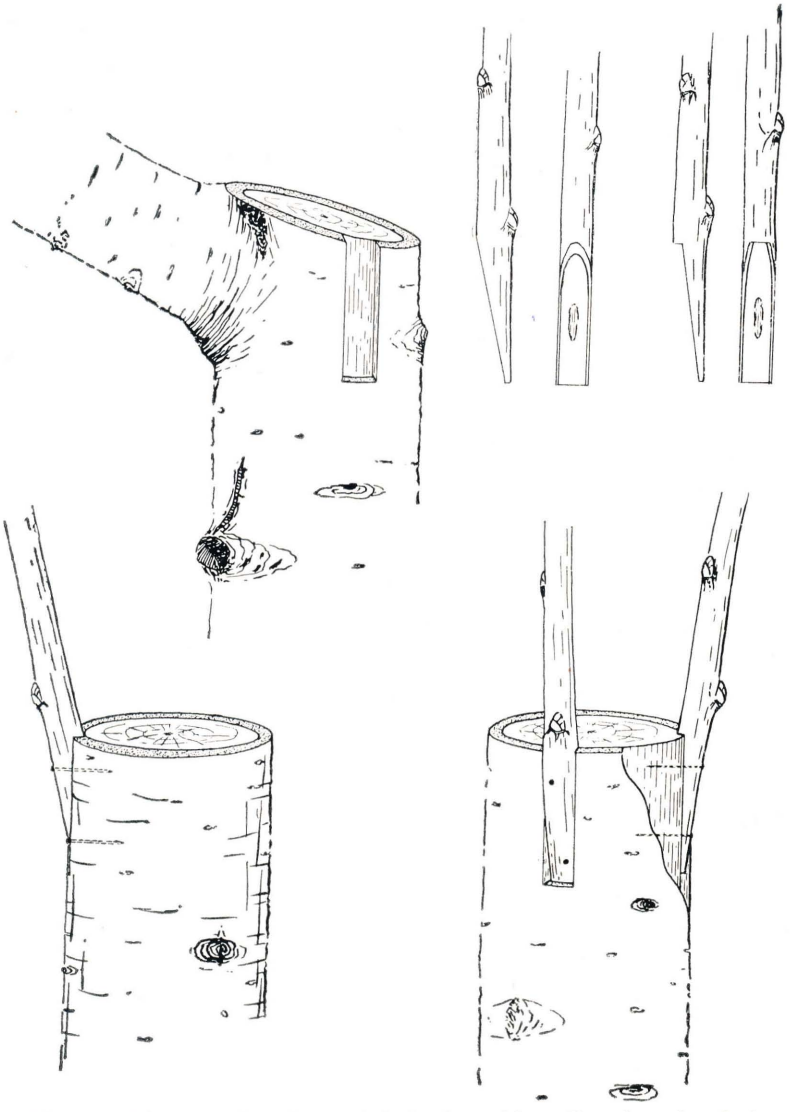

Fig. 18. The operations involved in bark grafting. For the sake of clearness the slot is shown too near the side limb to give full benefit to the "heel"; it should be opposite the limb. Cions may be set with a plain bevel or shouldered. This graft is not recommended for regular top working, since the cions blow out too easily.

It is questionable whether any kind of graft will consistently make a sound union on stubs too large for cleft grafting, and it is certain that bark-grafts—particularly on large stubs—are blown out very easily by winds of no extraordinary violence. It cannot be done advantageously until the bark slips. This graft may prove preferable with some stone fruits to obtain the greatest percentage of "takes," but it is not ordinarily necessary in the apple, pear, or quince.

The bark-graft may be made in very much the same way as the lower end of the inlay-bridge-graft, except that the bark removal starts at the edge of the wound (Fig. 18). Sometimes the cion is cut to a shoulder, or it may be cut with a plain bevel. Each cion may be secured with two thin small wire nails as in the bridge-graft. As in the other grafts, wax should be applied to all cut surfaces. Such terminal stubs should be recoated annually until healed to avoid drying of wood and invasion of fungi.

At the South Haven substation, bark grafting has been used very successfully for several years in top working pears, but less successfully with apples and cherries. In this work, a procedure differing from that just outlined has been used. Instead of the slot shown in the diagram, a single slit is made. The bark along this slit is raised slightly by the insertion of a thin and rather narrow smooth hickory wedge. The cion, trimmed with a rather long bevel on one side (the side to be pressed against the stock) and with little more than the bark removed on the other side, is then inserted inside the wedge and the wedge is withdrawn. The application of grafting tape to hold the cions and bark in close, followed by waxing, completes the operation. The principal advantage gained by this method is speed; the "take" is high and on pears at South Haven the wounds heal well. On apples at East Lansing, repeated trials of several methods have failed to obtain good enough contact at the top of the stub to produce good healing of the wounds.

THE INLAY-GRAFT:

Top working of large trees is difficult and impractical when work is confined strictly to cleft grafting stubs not more than 2 inches in diameter. A method has recently been devised, however, whereby new branches may be set at will on any limb up to 6 inches or even larger in special cases. This method is described at greater length in Michigan Quarterly Bulletin Vol. 21, No. 3, pages 184-191 (1939), so it will be described here only briefly.

This grafting is best done when the bark begins to slip freely (usually in May). The best cions are dormant one-year wood of the type ordinarily used in grafting; large cions are preferable, but those of ordinary size may be used. Cions are cut at points indicated by the lines A-B and C-D shown as A in Fig. 19. These cion portions may be 2 to 6 inches in length and may include one or more buds. The segment thus obtained is shaved on the side opposite the bud until the pith is barely exposed; it is virtually split in half as shown in cross section as B, Fig. 19.

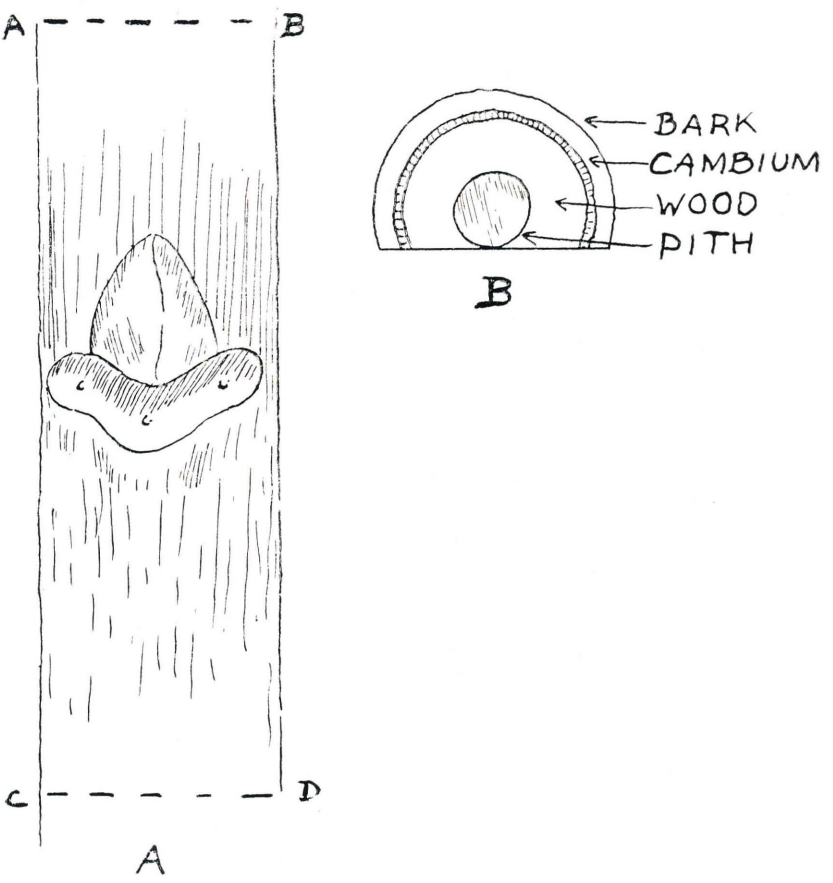

Fig. 19. Method of preparing cions. In A, the lines A-B and C-D mark the points where the cion is cut, though the cion is usually at least an inch long and may be two or more inches long and possess several buds. B, shows a cross section of the prepared cion.

At the point where the graft is to be inlaid, the outer corky part of the thick bark is sliced off with a knife, leaving a "fleshy" cortical portion of the bark. On this the prepared cion is laid parallel to the grain of the branch and its outline marked in the bark by tracing around the cion with a knife point. Remove the cion and with the knife retrace its course, cutting down to the wood; the piece of bark is then removed and the cion inserted with its cut face against the surface of the exposed wood. The cion is pressed and held against the surface of the wood with two small wire nails. Parallel to the cion and about 2 inches from it a cut is made in the bark on either side extending an inch or two beyond each end of the cion. This is to keep the expansive growth force from pulling the bark away from the edge of the cion. The entire cion is coated with grafting wax, including the cut

edges of the bark surrounding the cion, but not over the parallel relief cuts to the side of the cion. Nothing further is needed.

With very little practice, an agile worker can set 25 of these inlay-grafts well scattered over the scaffold limbs in an hour. Most of them will grow the first year, but some may lie dormant a year. The total "take" of these cions, in a vigorous tree, with some of the outer branches removed, averages as high or higher than that obtained from ordinary grafting.

Fig. 20. A close view of the test tree, showing some of the new limbs induced by placing modified inlay-grafts. The slit on either side of these limbs is the healed-over tension release slit cut on either side of each cion as described in the text. The best of these may now be saved for permanent limbs.

These cions should be placed where they can be used most advantageously in developing a new top (Figs. 20 and 21). They should not be set on vertical or nearly vertical limbs or portions of limbs, because in such positions the growth from them often forms a narrow-angled crotch. They should not be placed on the exact top of diagonal or horizontal branches, because in older trees the callus formation requisite to union is slow at this point. A few degrees to the side of this top line seems to be the best location, considering both the immediate success of the grafting and the ultimate growth of the new branches (Fig. 22).

It is probable that in most cases a small amount of cleft grafting at the tip of each scaffold limb will be desirable to avoid leaving a stub. This is a place where the bark-graft might be used to advantage. Desirable water sprouts should be cleft-grafted or whip-grafted. In short, the inlay-grafts

Fig. 21. Tree top-worked by inlay bark grafting, spring, 1940. Picture taken February 1943.

should be placed where no suitable limbs remain and where new limbs are desired. The laterals, however, can be removed gradually and replaced by the growths from the new grafts. Thus with a total expenditure of much less labor than is involved in the usual cleft grafting and with much less interruption of cropping, a rather large tree can be worked over into a tree more easily handled in later years than the one grafted high. The point should be emphasized, however, that a tree that is not vigorous is hard to top-work satisfactorily by any method.

It should be stated that limbs produced in this manner are still comparatively young (9 years), and some doubt may be raised as to whether they will tear out under the combined stress of crop, rain, sleet and wind. Present indications are that the limbs will be satisfactory, unless they are forced to inordinately rapid growth. Water sprouts which develop into fruiting branches usually are well enough anchored to withstand usual stresses, and branches from this type of graft have an anchorage in the parent more extensive than that of most water sprouts.

Fig. 22. Two inlay-bark-graft cions set to produce low limbs of a better variety. They are shown as coated with asphalt grafting compound.

A final precaution should be mentioned. In renewing an old tree by any method, sunscald is its worst enemy. If sufficient growth is not present to protect all bark on the top of main limbs, a whitewash of cold water paint should be applied to the most important scaffold branches soon after the grafting is done.

THE TONGUE- OR WHIP-GRAFT:

The tongue- or whip-graft is particularly suited to cases in which the cion and the stock are of approximately the same size. Under such conditions it is superior to the cleft-graft because of the quicker healing obtained. The more nearly the stock and cion approach equality in size the greater is the probability of success with this method. In the orchard this graft is used especially for top working young apple and pear trees where the small sized branches are still low and close to the center of the tree. In the winter this method is used inside, mostly in the middle west, for grafting cions onto seedling roots in the propagation of nursery trees. In this case it is generally referred to as "bench grafting". In the tongue-graft, both stock and cion are cut to match. A uniformly sloping cut, from one to one and one-half inches long (the larger the cion the longer the cut), is made in each. On both stock and cion a slit is made, beginning at a point one-third of the distance from the "toe" (sharp end) to the "heel" (Fig. 23). This slit may run exactly with the grain, or it may cut across the grain slightly in the general direction of the heel.

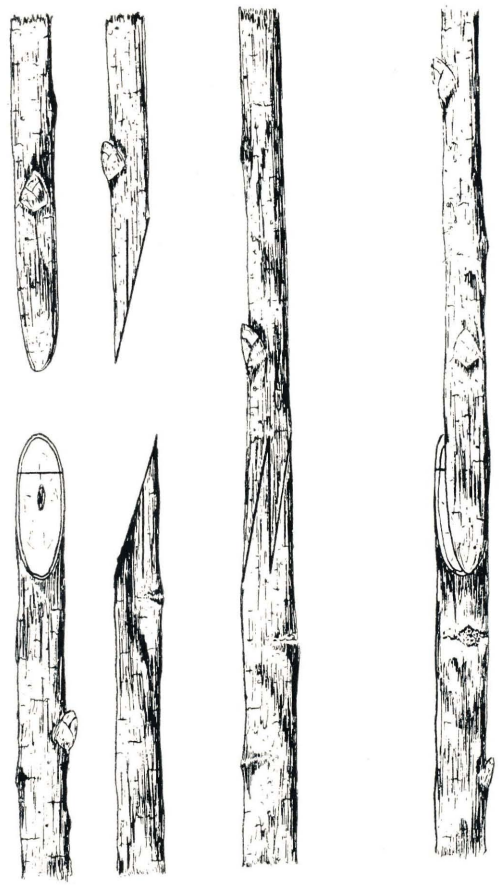

Fig 23. Tongue- or whip-graft. From left to right: (1 and 2) stock and cion ready for grafting; (3) cion in place. Note three contact surfaces; (4) placing of cion on larger stock.

If the cion is smaller than the stock, it must be set on one side to secure cambial contact at the tongues (Fig. 23). When this is properly done, cambial contact is obtained on three surfaces.

If, when stock and cion are united, the toe of either projects much beyond the heel of the other, it should be cut off even. This can be done without disturbing the graft. The slow healing resulting from failure to correct this condition is shown in Fig. 24.

Tying the tongue-graft is advisable for best results. In the orchard the completed graft must be waxed to insure a satisfactory union. Waxing is just as essential in this as in the cleft-graft, and if tying is omitted it serves the additional function of holding the cion in place. As in the cleft-graft, great pains should be taken to make the wax coating air-tight, as all cut surfaces including the tip of the cion should be covered with wax.

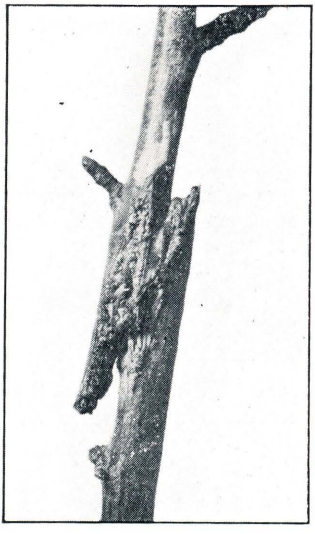

Fig. 24. Imperfect healing in tongue-graft resulting from improper fitting of cion and stock.

When this type of graft is used in bench grafting, the grafts are always tied and seldom if ever waxed. As soon as bench-grafts are made they are packed immediately in moist peat-moss and stored in some cool place until ready to be set out in the nursery. The moist peat-moss around the union prevents drying out and increases the formation of callous tissue. For tying, a number 20 waxed string or a special type of adhesive tape made for this purpose and known as "nurserymen's tape" may be used.

Beginners' most common faults in attempting this graft are: (1) failure to make the sloping cuts long enough; (2) uneven slopes arising from dull knife or failure to support the twig properly from the back when making the cut; (3) improper placing of the slit, and (4) failure to press the tongues in deeply enough. All of these reduce the surfaces of actual close contact, often sufficiently to cause failure or very slow healing with consequent danger of infection by wood-rotting fungi.

BUDDING:

Budding is a form of grafting in which a bud rather than a piece of stem is inserted upon the stock. It is a method of propagation used mostly in the nursery to propagate new trees. However, it may also be used in the orchard to top-work young peach trees that have not proved true to name or where a few trees or limbs need to be budded to a variety to provide suitable pollen for fertilizing blossoms of a sterile variety. It is sometimes useful for apple trees that are either untrue to name or that are being double-worked so as to produce a tree with a hardy or vigorous trunk and framework. In top working stone fruits (peaches, plums, apricots, cherries), budding is preferred to grafting, because the wood of these fruits

does not split well for grafting and gum formation is excessive, while in budding, the bark "slips" readily and bleeding, if it occurs, is not detrimental to a union.

The best time for budding is late summer or early fall. At this time the buds of the current season's growth have matured and the bark on the stock is slipping readily and is in a good condition to bud. Buds are taken from vigorous shoots of the current season's growth. Those from the center two quarters or mid-section of the shoot are better than those from the base or the tip, as previously stated regarding cions. The budsticks are cut from vigorous shoots and the leaves trimmed off, leaving a short piece of the leaf stem which may be used as a handle in the budding operation. The budsticks are then wrapped in moist burlap to prevent their drying out until ready for use. In top working established trees, the buds are placed on the top of the limbs; one-year-old wood being the best on which to bud. The thicker the bark the less likely are the buds to grow; also, buds that become grown over are very difficult to force into growth.

At the point where the bud is to be inserted a T-cut is made in the bark, the transverse cut being made by a rolling motion of the knife and the vertical one by drawing the knife upward lightly from a point about an inch below the first cut. Many old-time propagators carry quills from the wing feather of a large fowl. This is cut to a sloping bevel and is carefully inserted into the T-cut to open the edges of the bark and facilitate the insertion of the buds. If trees are in the proper condition the bud alone will open the cut. Next a bud is removed from the bud stick in the shape of a shield. The knife is started about one-half inch below the bud with a drawing motion of the blade cutting under the bud into the wood only deep enough to prevent injuring the eye or bud and crumpling the shield. It is not necessary to remove the small piece of wood adhering to the bark. The bud is removed from the budstick by a transverse cut about ¼ inch above the bud and inserted into the T-cut, pushing it firmly in place by using the leaf stem as a handle so that the bud fits snugly against the cambium of the stock. It is important to have the tip of the bud pointing upward because inverted buds do not make very good subsequent growth. The bud must next be tied in place by wrapping with string, raffia, rubber budding strips, or other suitable material. In tying the bud it is essential that the bud be firmly tied and that the bud itself be not covered. In about two weeks the wrapping should be removed, care being taken not to injure the bud. If the bud has united with the stock it will have a healthy, plump, appearance but if it has failed to unite it will appear brown and shriveled. In this case the stock should be rebudded.

The following spring, as soon as the buds begin to swell, the stock should be cut off just above the bud which was inserted the previous season in order to force it into growth. During the season all shoots originating

below the bud should be removed in order to force growth into the shoot developing from the inserted bud.

SUBSEQUENT CARE OF GRAFTS:

Care of the grafts even after they are well established is important and

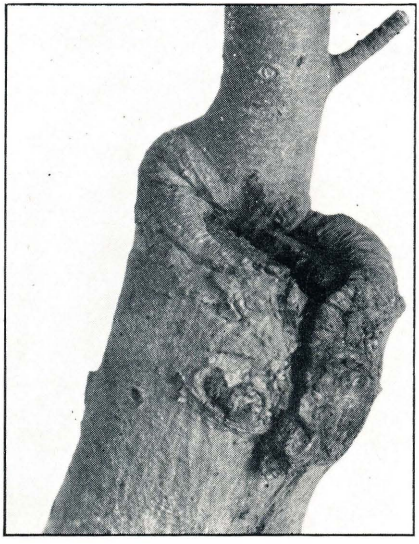

Fig. 25. Slow healing and decay from premature removal or failure of second cion.

should not cease until the union is completely healed over. Two purposes should be kept in mind in this work: (1) the prevention of invasion by wood-rotting fungi (Figs. 25 and 26), and (2) the formation of the framework of the new top. In addition, protection against climbing cutworms, aphids and fire blight may be necessary, particularly in the first year. Within a short time after the grafts are set they should be examined for defective waxing, and rewaxing should be done each fall and spring until healing is accomplished. Complete rewaxing is not necessary; ordinarily callus formation will seal the sides of the cleft in the first summer, and they will require no further

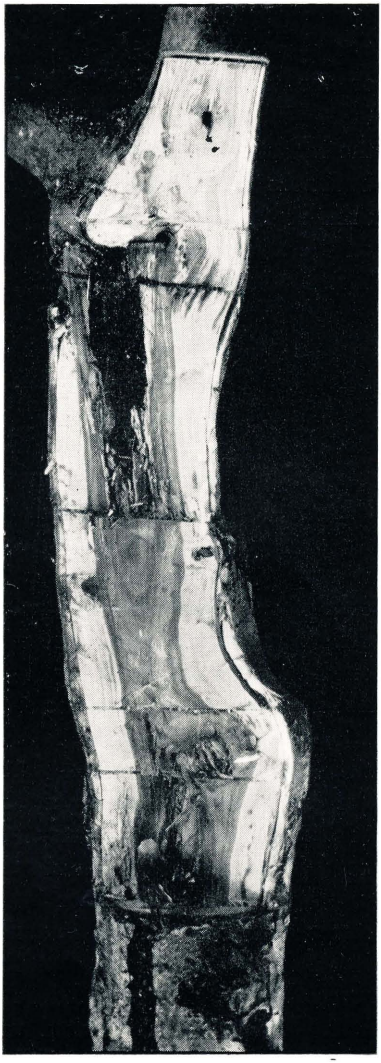

Fig. 26. An inside story with the same moral as Fig. 25. This limb was grafted twice. The lower union is sound; decay started in the upper before the retarded healing could seal the union.

attention. At the top of the cleft, however, several renewals may be needed. If the wax is at all hard and lacking in pliability, the expansion of the cions through growth is likely to cause it to buckle and loosen. In such cases all loose pieces should be removed and fresh wax applied. This is not necessary if asphalt emulsion is used.

About July 1, in the first season of growth, pinching back of the vigorous shoots from the cions may be desirable. This is done to induce low branching and to keep the framework of the new fruiting top as close to the ground as possible. Only the soft green wood at the very tip should be removed; this may be done with the thumb and forefinger. Heavier cutting back would have a somewhat stunting effect and should not be practiced at this time.

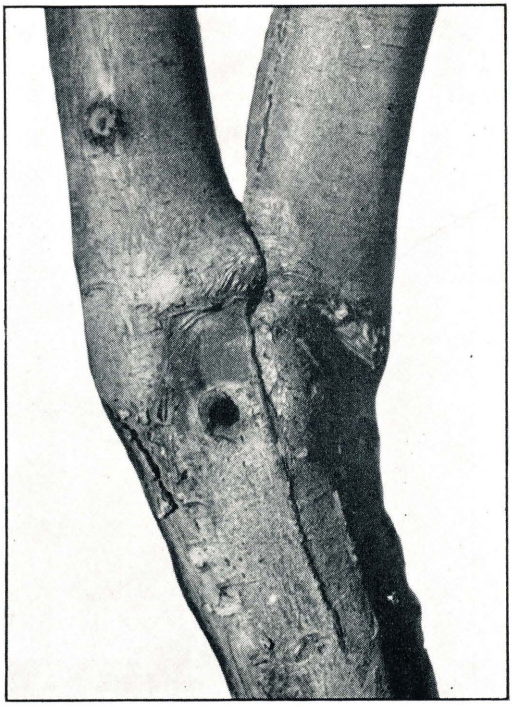

Fig. 27. An old graft with cions crowding; a source of weakness. One cion should have been removed long ago.

Both cions on each stub should be allowed to grow for a season, at least. Eventually one is to be removed, because if both grew to full size a weak crotch would be formed, as the new wood on the inside of each cion pushed against the other cion, and splitting out would be likely, just as in an acute-angled crotch (Fig. 27). For a time, however, both are needed to keep the stump alive throughout. On a two-inch stump a cion will induce callus formation on the corresponding half of the circumference, but because of the slowness in the lateral movement of food materials coming from the growing cion, it is unable to supply the opposite side sufficiently to maintain life and this part of the stump may die. To make a good union all of this dead area must be sealed in by growth from the edges—always a slow process—and before this can take place decay is almost certain to begin (Figs. 25 and 26). If, however, live cions on both sides are feeding the stump, it remains alive in every portion. If one cion fails, any nearby water sprout should be saved for a time and treated as the "subordinate-cion" (See next paragraph).

Growth proceeding from one of the two cions on each stump should be

kept distinctly smaller than that from the other, so as to prepare for the ultimate removal of the smaller cion. If both make equal growth the removal of one will leave a relatively large wound which may be slow in healing (Fig. 28). A cion kept small for several years will suffice to prevent the death of any part of the stump and when it is removed will leave a small wound. In the meantime the other cion will have attained considerable size and will be able to supply enough food materials to heal the small wound in a short time.

The subordination of one cion is effected by pruning it more heavily than its companion. This differentiation may begin at the time of pinching in the summer following the setting of the grafts and should receive attention each succeeding spring while the cion is retained.

Fig. 28. The temporary "subordinate-cion" should be kept smaller than the permanent cion, by frequent heavy pruning, so that when it is removed the wound will be small and will be healed quickly (left and center). Figure on right shows a case in which the "subordinate-cion" (the one pointing toward the camera) is being developed into a small lateral branch and will not be removed.

The removal of the subordinate cion should not occur until the bases of the two cions meet across the end of the stub. This time will vary with the vigor of cion growth and with the size of the stump. With vigorous growth on the smaller stumps, removal can occur in many cases in one year; in others the period may be three or four years. When the cut is made it should be close enough to leave no projecting stub.

Water sprouts should not be removed indiscriminately. Their utilization is discussed under "Top Working".

REPAIR GRAFTING

GENERAL CONSIDERATIONS:

One of the several hazards of fruit growing is the danger of injury to the trunk and roots of the tree through various causes. During the winter rabbits and mice become hungry and often satisfy their appetites by eating the bark of tree trunks, especially those of the apple and pear and sometimes even cherries, peaches, and plums. In their anxiety to have a good meal they often eat down into the cambium and so cause partial or complete girdling of the tree. A very cold winter may also injure the trunks of tender varieties, while occasionally even hardy varieties may be split open lengthwise of the trunk. Some varieties are susceptible to "collar rot," many are subject to bacterial fire blight, each of which may so injure the root system or trunk that some repair work must be done to save the tree.

In repairing trees girdled by rodents wholly or in great part, two things must be remembered: (1) The trunk must be relied on to carry water to the tops of the trees until the bridge grafts have attained some size. This involves protection against drying out of the wood from which bark has been removed. (2) The bark connection between top and roots must be restored or the roots will die. This involves bridge grafting, which will be discussed presently.

The steps to be taken immediately upon discovering the injury (at least by early March) are: (1) protection against drying out of exposed areas by the application of a coat of asphalt water emulsion, which will adhere to moist surfaces, high-grade shellac, or the resin-alcohol repellent referred to later, (2) cutting cions and storing for use in repairing cases that justify the effort, (3) insuring against future rodent injury by utilizing protective measures as briefly discussed later in this bulletin.

In choosing cions for repair work, it is suggested that only hardy and disease-resistant varieties be collected. Suitable apple varieties include Arkansas, Duchess, Fameuse, Hibernal, McIntosh, N. W. Greening, Virginia Crab and Wolf River. Those to be avoided because of tenderness or susceptibility to disease include Baldwin, Ben-Davis, Delicious, Golden Delicious, Gravenstein, Grimes Golden, Jonathan, King David, N. Spy, R. I. Greening, Rome Beauty, Spitzenburg, Stark, Stayman Winesap, Tolman

Sweet, Wagener, Winesap, York Imperial, and Winter Banana. With respect to pear varieties, the relative resistance to fire blight is the important consideration. The following varieties are suggested in the order of their resistance: Old Home, Keiffer, Seckel and Winter Nelis. Standard varieties to be avoided include Bartlett, Bosc, Clapp's Favorite, Flemish Beauty and Howell. It would be short-sighted to rescue a tree by repair grafting only to have its grafts killed by low temperature or blight.

PROTECTION OF TREES FROM RODENT INJURY:

Repair grafting is a tedious, time-consuming job, and is made even more annoying when it is realized that adequate precautions in the fall could have saved much of this work. These precautions are inexpensive in time and money as compared with the time involved in setting necessary grafts for the girdled trees. The principal precautionary measures for rodent protection consist in wrapping or painting the trunks with suitable material which will prevent these rodents—chiefly field mice and rabbits—from eating the bark off the tree trunks. As a protection against both mice and rabbits, quarter- or half-inch mesh hardware cloth may be tied around the tree. This wire cloth should extend from 2 inches below ground level to 12 to 18 inches above ground and should be loose enough to allow for future expansion of the trunk. If hardware cloth is not obtainable, window screening, thin wood-veneer tree wrappers, lath, or even corn stalks tied around the trunks will, in the order named, afford a certain measure of protection, though it is doubtful if anything but wire will keep out field mice. When wire is not used, the rodents in question must be controlled by different methods.

To control mice, especially where sod exists near tree trunks, it is recommended that poison bait be placed in mouse runways each fall to rid the area of as many field mice as possible. Such agencies as Grand Rapids Growers' Association, Grand Rapids, Mich., have been authorized to sell poison bait prepared by the United States Department of Agriculture.

To protect the tree from injuries caused by the cottontail rabbit, the application of a repellent varnish to the tree trunk has proved very satisfactory. This varnish is made by dissolving approximately a pound of powdered resin in a pint of high grade radiator-type ethyl alcohol and shaking frequently until most of the resin has been taken up by the alcohol. This material should be stored in a warm place in a tightly stoppered glass container. For field use, pour into convenient containers and apply to the surface of dry bark. This preparation may be purchased from dealers of bee supplies and grafting equipment.

CARE OF WOUNDS:

As soon as a wound has been discovered on a tree, immediate steps should be taken to reduce the injurious effects to a minimum and promote

rapid healing of the wound. Protection and healing of a wound must be considered together because often the promotion of protection may inhibit healing. Protection of a wounded surface involves prevention of drying out on the one hand and prevention of fungous infection on the other. Therefore, wound protection may be accomplished by covering the exposed surface with a coating of some material that is non-injurious to plant tissue. Wound healing may be accomplished either by callus formation from the side of the wound, or by regeneration from the surface of the wound (see Fig. 29). Healing from the side is more common in winter wounds, but surface healing, or regeneration, though less common except in wounds made during the summer, is more rapid and, therefore, more important, and involves the preservation and care of the cambium layer.

Wounds made in the winter should be trimmed around the edges to remove rough bark and then painted immediately with asphalt emulsion or suitable grafting wax. Drying severe enough to cause checking of exposed sapwood on live trees occurs in March or April. If the cambium has been

Fig. 29. Two kinds of wound healing. On the right the cambium was not destroyed and bark regeneration occurred directly on the wood; on the left the cambium was destroyed and healing is accomplished by the slower process of callus growth from the edges.

destroyed, prompt care will prevent excessive drying and splitting of the wood. However, if the injury has been superficial and the cambium has not been badly damaged, such as when mice fail to reach the cambium, prompt painting with a suitable material will prevent the cambium from drying and hence will promote regeneration of the destroyed bark from the cambium.

When wounds are made during the growing season, especially in early spring and summer when rapid growth is taking place, a somewhat different treatment should be given according to the type of wound. The proper treatment of a wound made by a tillage instrument tearing off a considerable piece of bark when it is slipping freely is to leave such a wound absolutely alone. The warmer and drier the air at the time, the greater appears to be the chance of healing by regeneration of bark all over the wounded area, if the exposed surface is not touched. This is quicker and much more satisfactory than healing by callus formation from the side. In cases where the bark has not been torn off the tree, immediately nailing the bark back in place will usually insure prompt healing of the wound.

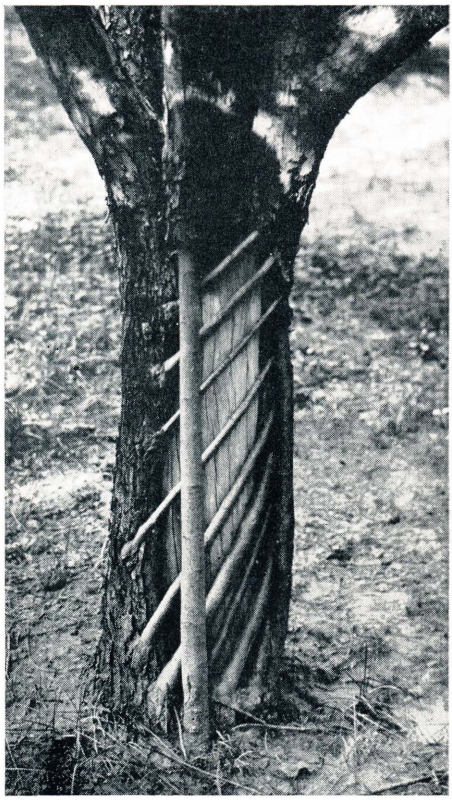

Fig. 30. Bridge-graft. Note the more vigorous growth the more nearly vertical the cions are set. Note also the checking in the wood of the trunk; this wood should have been protected before the cions were set.

THE BRIDGE-GRAFT:

A bridge-graft (Figs. 1, 30 and 31), as the name implies, is used to bridge over an area where the cambium is dead. In practice it is used most frequently in Michigan to repair damage from gnawing by mice or rabbits or occasionally from bark peeling by sheep. More use should be made of this type of graft in repairing damage from fire blight cankers on the trunk and from winter killing.

At this point, a word of caution may be introduced. Bridge grafting is no small consumer of time and labor, and in some cases careful study will show a means of avoiding this work with satisfactory results. Sometimes,

Fig. 31. A typical case of complete girdling by field mice. Many valuable trees so injured are saved by early treatment of the wound and successful bridge grafting. At left: cions properly set and waxed. Right: old bridge-grafts which have grown together to form a new trunk.

mice apparently ring a tree, gnawing the bark completely around the trunk, but actually fail to touch the cambium. If attention is given before drying out has occurred, simply mounding with earth or wrapping with waxed cloth will be sufficient to permit regeneration of the bark.

On trees which have been girdled within one or two or even three years after planting, the advisability of bridge grafting is doubtful; it will probably be cheaper and in the end more satisfactory to saw them off below the injured area and cleft-graft them. Reliance should not be placed in sprout growth under these circumstances. In many cases the trees so treated will not sprout at all; if they do, many of them will sprout only below the graft and most of these sprouts that do come from above the grafts will be slow in starting and slow in growth. The setting of cions, even though no change in variety is desired results in surer, quicker growth, and, provided the grafts receive proper subsequent handling, induces a more rapid healing and a better shaped tree.

With all these qualifications, however, the cases of real need of bridge grafting are numerous. The cost of the operation, balanced against the prospective or actual capitalized value of an established tree, is generally very small. The grafts grow readily, and when the need is indicated the work should be undertaken.

Bridge grafting is not readily accomplished until the bark on the tree slips well, usually about the first week in May for lower Michigan. Before this time, raising of the bark is very difficult, and if it is accomplished at all, much of the inner bark remains attached to the wood. This interferes with the attainment of cambial contact, and scraping down to the wood surface is very exacting and laborious. On the other hand, grafting much later may be reasonably successful. Damage from mice or from winter injury is sometimes unnoticed until attention is drawn to the injured tree by a yellowish tinge of the foliage in June. In such cases, as an emergency measure, bridge grafting may be done in early summer. Bridge-grafts spanning old injuries in mature apple trees at East Lansing and in certain injured orchards, made in the first part of July, were very successful. For this summer work, however, careful selection of cion-wood is necessary. There is, ordinarily, no special advantage in summer grafting of this type, and it is recommended only as an emergency measure.

Cion-wood for the bridge-graft is of the same character as that used in other grafts, so far as age and vigor are concerned, but special effort should be made to obtain large cions. For summer work, the wood of the previous year should be used; at this season, the basal portion of the wood of the current season may be employed if satisfactory older wood is not available, particularly if it is ringed a week or two before it is cut. Since fruiting wood ordinarily will not be developed from bridge-grafts, the variety from which they are taken is of no consequence, except that hardy, blight-resisting varieties as previously listed on pages 39 and 40 should receive preference.

Good condition of the wood surface of the tree at the points of contact with the cions is very important in bridge grafting. Microscopic examination of sections through several bridge-graft unions made in the laboratory of the Horticultural Department indicates that a large part of the callus tissue through which connection is established comes from this wood rather than from the cions. This fact has special application in bridging areas which have been dead for some time, since in such cases the tissue for some distance from the area originally killed may be alive but in such poor condition that grafts set in it will not "take" well. Whenever practicable, the tree should be prepared for the setting of the cions a day or two before the actual grafting is done. All dead bark should be removed and, if the wound is old, any unhealthy live bark should be removed. Unless the injured area extends for such distance on the trunk that the obtaining of cion wood of suf-

ficient length is difficult, there is no special need of pains to keep the bridge area short, because proper unions can be made more easily with long cions than with those which are very short.

If exposed surface is covered with asphalt grafting compound, the material should have been applied a day or so in advance of setting cions in order to give the asphalt sufficient time to dry and thus facilitate the work.

The purpose of this protection is twofold—(1) to guard against invasion by wood-rotting fungi and (2) to keep the sapwood from drying out.

The various methods of setting cions depend in common on obtaining contact between the surface of the wood on the tree and a bevel or sloping cut on the cion. In some forms of the bridge-graft, an additional contact may be obtained with the bark of the tree, but this is by no means essential.

Dependence on contact through a bevel cut on the cion virtually necessitates a spring or bow in the cion as it is finally set (Fig. 32). An additional advantage of the spring is to provide a small amount of slack which will permit some swaying of the tree without disturbance of the union. If the cion is somewhat curved, the bevels should be cut on the concave side. The spring is secured with a straight cion by cutting it slightly longer than the distance it will cover when set, fitting one end in position, securing it by one or two No. 18 wire nails with slender shafts and wide heads, and then springing it into place and nailing it at the free end. If the cion is as large and hard as it should be and the "spring" sufficient, the nails may be set in very slightly to draw the bevel cut close to the wood and therefore in contact with the cambium.

One cion for each two inches in the circumference of the tree will be sufficient (Fig. 31).

If the cions available are not long enough to span the dead area, they may in some cases be set diagonally with fairly satisfactory results, but vertical placing is preferable (Fig. 30).

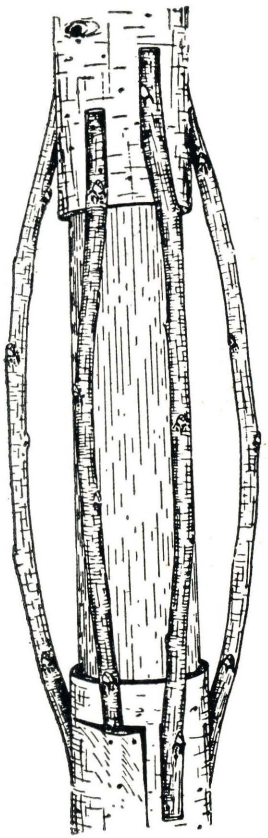

Fig. 32. Bridge-graft, showing some of the many methods of setting cions. Note the spring on the cions. This is particularly important in young trees, which sway most.

Cions should be set "right end up," i.e., as they grew on the tree, but, if through inadvertance any are set upside down, it is not necessary to replace them. Inverted cions have been observed growing in considerable numbers.

The simplest and, where it is feasible, the most easily made union involves an L-shaped cut in the bark (Fig. 33). Below the wound the L

is inverted. Each arm of the L is about one and one-half inches in length and each is cut an inch or two from the edge of the wound. The cion is beveled at either end principally on the side destined to be set against the tree; the other side is beveled sufficiently to give a rather sharp angle to the wedge. The bark in the angle of the L cut is raised sufficiently to admit the cion, which is then inserted and nails driven through the bark and the cion. Nailing the bark is necessary because it is very difficult to bend the bark back sufficiently to set the nail directly into the cion without injury to the bark because at this season there is a tendency for the bark to shrink wherever it is cut vertically and its great tension relieved. This union is best suited to trees with thin or only moderately thick bark.

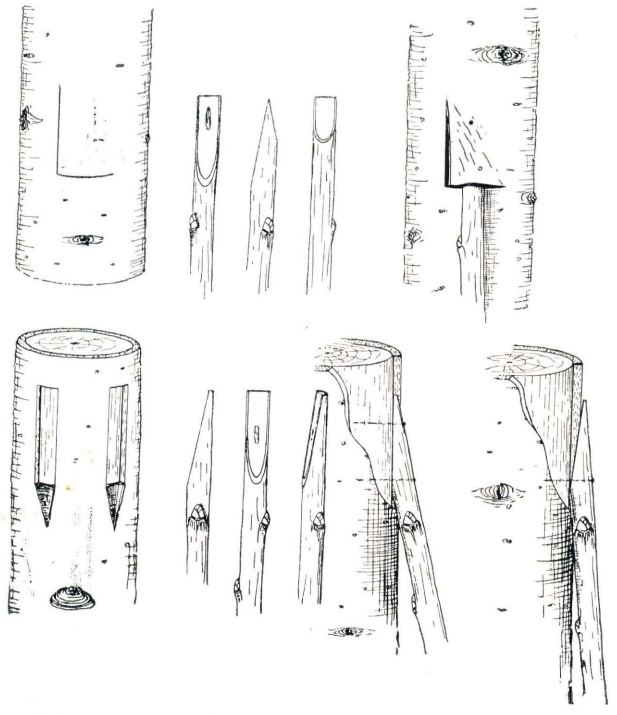

Fig. 33. Two of the numerous methods of fitting cions to stock in the bridge-graft. Above: the L cut, with trimmed cion. The long bevel of the cion goes against the wood; the contact is between the cambium surface of the wood and the cambium line of the cion. Below: the inlay, a method suited to trees with very thick bark. The notches below the slots shown on the left may or may not be necessary. On the right: one way to make grafts fail is through a cion somewhat too short and consequent lack of sufficient spring to ensure contact.

For trees with very thick bark or for cases where cions are set into the roots, the inlay-graft is preferable. This union has a further advantage in that the ends of the cions are not cut down so thin, and they are less liable to damage from nailing. The bevel cut is very long, perhaps three or four inches, but it does not extend to the opposite side (Fig. 33). With the cion prepared, the operator holds one end against the bark at the spot it is to occupy and traces around it with the knife, marking on the bark, and the piece just outlined is removed. In thick-barked trees, much time may be saved, at no cost to the tree, by shaving the corky bark where the graft is to be set, leaving the cortex or green bark, against which the mark may be made and in which the slot is cut. The cion is then set in and nailed at this end and the process

repeated at the other end. This union requires somewhat more skill than that previously described and generally takes more time.

Modifications of these unions are sometimes employed. In very thick barked trees, the cions are sometimes cut to very thin wedges and forced under the bark at the edge of the wound. This method is hard on the cions as the wedge is frequently bruised and short cions are sometimes broken in springing them sufficiently to slip under the bark. Furthermore, the thinness of the wedges makes them more likely to be injured from nailing. Some operators slit the bark vertically at the edge of the wound and set the cion directly under the cut so that it raises both flaps of the bark. In this union, however, satisfactory nailing is rather difficult, the flaps of bark make little contact with the cion, and proper waxing at the upper end is generally more difficult. Even though the cut is necessary to permit the raising of the bark, the cion should be set under one flap or the other.

Mr. H. D. Hootman, of the Extension Service, has been very successful with a simplification of the slot method which effects a material saving of time and should, in most instances, make adequate cambium contact more certain than that often attained with the slot method just described. Where grafting is done soon after the injury occurs (first season) it is preferable. In older cases it is often necessary to go farther from the exposed area; in these cases, according to circumstances, use of the regular slot graft may be necessary, or the best course may be to clear away all doubtful bark and use the simplified method.

This modified method may be described as the open slot. The slot opens directly on the edge of the exposed area as in the second from the left on the upper edge in Fig. 32, but the bark is not removed; it is merely lifted, being cut only on the edges of the slot and "hinged" at the uncut end. The cion is trimmed as shown in the upper row of Fig. 33 and pushed under the bark, and nailing is done through the bark.

Whatever the type of union employed, all cut surfaces should be covered with asphalt grafting compound or grafting wax. Considerable care will be necessary to obtain tight sealing in the angle between the tree and the upper end of the cion, because the wax must be applied and set against the downward pull of gravity. The edges of the ringed area also should be covered.

As soon as grafting and wound covering are completed, soil should be replaced. Raising a slight mound may be helpful because mice have sometimes returned to attack newly set bridge-grafts. This filling should be done with some care, lest clods of earth displace the newly set cions. Occasionally, the extra moisture thus insured induces rooting in a cion (particularly in Spy) which has failed to unite at the base, and thus prevent its becoming an entire loss.

Young bridge- or approach-grafts are subject to injury from rodents and

Fig. 34. The result of costly carelessness. Approach-grafts established 15 years girdled by rodents but not noticed before they had died. Annual vigilance is the only method of prevention.

should be given the same adequate protection afforded young trees to avoid the type of repeated injury as is shown in Fig. 34.

THE APPROACH-GRAFT:

The progress of fire blight cankers on tree trunks, extensive collar rot, or trunk injury of long standing effecting a partial ringing, may lead to the

death of some of the roots. This in turn is likely to be followed by the death of limbs originating in direct line on the grain of the wood, generally directly above the injury but sometimes, in trees with twisted grain, several

Fig. 35. This orchard of hardy McIntosh growing near Grand Rapids began to lose about 20 trees a year after it was 10 years old. Examination showed that cultivation and very slight soil erosion had lowered the soil level so that as each tree had its bud union and weaker seedling root stem exposed it became girdled. Eighteen years ago the owner planted four hardy trees about each McIntosh and approach-grafted the tops into the trunk. Very few trees have been lost since that $1.50 investment was added to each tree.

points of the compass to one side. In any case, death and subsequent rotting of any considerable portion of the roots weaken the anchorage of the tree in the soil and may lead to its leaning or falling over.

Under these conditions, trees rarely form new roots to replace those lost because the main body of the stump itself is generally involved. However, young trees set in the soil close to the old tree and connected with it by grafting the top into the trunk like the upper end of a bridge-graft, form new roots with great rapidity (Fig. 35). As a preliminary measure, obviously, in case the injury has been caused by fire blight all diseased area should be scraped and disinfected. The actual graft union may be made by any of the methods used in bridge grafting. Seedling trees may be used for this purpose. One-year-old seedlings as obtained from wholesale nurseries are rather small, but two-year-old seedlings are generally large enough. If budded or grafted trees are used, preference should be given to hardier, blight-resisting varieties.

Fig. 36. Bacterial fire blight killed a large portion of the bark on one side of this Bartlett pear tree. Because it occurred early in the summer many long sprouts were forced out below the injury. Had the owner not been alert these might have been pruned away, whereas, he had only to insert the upper ends into the bark and the injury was bridged.

Injury to the trunk or collar may have been followed by the growth of suckers, or water sprouts, from below the injured area (see Fig. 36). If these are of sufficient length, the tops may be grafted into the sound wood above the injury, remaining attached below unless the variety is very susceptible to fire blight, in which case a more resistant variety should be used.

PROPAGATION IN THE NURSERY

Fruit trees are best produced by the commercial nurseryman who has the training and facilities to raise first-class nursery stock. There are occasions, however, when a person may wish to raise a few trees for his personal use. In such cases a knowledge of how trees are produced may be extremely useful.

Stocks for fruit trees are usually raised from seeds, the resulting seedlings being budded to the desired variety. In the case of apples and pears, seed from most of the commercial varieties is satisfactory. However, seed from the following apple varieties should be avoided on account of the poor growth that the resulting seedlings make: Baldwin, Gravenstein, Hibernal, Tompkins King, Rhode Island Greening, Stark, Stayman, Winesap and Virginia Crab. Peach stocks may be raised from most commercial varieties, though Elberta, South Haven and Rochester do not germinate so well as some of the other varieties such as J. H. Hale, Gold Drop, and some of the lesser known varieties as Kalamazoo, Barnard, Prolific and Fitzgerald. Stocks for plum and cherry trees are best purchased from a wholesale nursery. Apple and pear seeds may be planted early in the fall in rows and ridged up about 2 inches. The following spring this ridge is smoothed down. The resulting seedlings are grown for a season, dug, graded according to size, and stored in a cool, moist place until the following spring. The larger ones are then set out about 6 inches apart in the row and later budded to the desired variety. The stock is prepared by rubbing or cutting off the lower leaves and branches so as to leave a smooth place on the bark on which to work. The bud is then inserted into the stock about one inch from the ground and tied with suitable material. The technic of budding has already been described. Peach seeds may be planted in the fall, and the resulting seedlings budded the following summer. Plum and cherry seedlings are budded the same season that they are set out. Stocks are budded during the summer when the bark slips readily. Apples and pears are usually budded first, starting in July and followed by plum and cherries, while peaches are budded last, generally in late August.

The spring following budding, just as the buds are breaking, the stocks should be cut back to just above the inserted buds. This forces the buds which were inserted the previous season to push out and develop a vigorous shoot, which at the end of the season will have produced a one-year-old nursery tree ready to set out in its permanent location.

The production of a fruit tree extends over several years. When the stock is raised from seed, it will take in most cases three years to produce a one-year-old tree ready to set out in the orchard. Peach trees may be produced in two years, owing to the quicker rate of growth of seedling stock.

GRAFTING NUT TREES

There is so much inquiry about planting or grafting wild nut trees to better named strains, that a brief comment on this subject may help those interested.

At best one should recognize the fact that it is often difficult in cold, changeable climates to establish a young transplanted nut tree and have it survive to full bearing age. Complete failure is more often the rule than the exception. The trees should be planted in the fall or as soon as frost is out of the ground in the early spring. The trunks should be wrapped with heavy paper or strips of burlap to prevent drying out and also to prevent sunscald injury. Where trees are already established, it should be easier to graft cions of named strains than to transplant young trees, especially if the soil is not extremely fertile and well drained.

Bleeding of cut limbs of most species of nut trees has always been considered the cause of failure to get cions to unite with the stock. A one-season test by the senior author, described in the 1938 Report of Northern Nut Growers' Association, between trees cut 10 days before grafting and those cut at the time cions were set, showed no difference in favor of pre-bleeding. However, it is much easier to apply a coating of grafting wax or asphalt water emulsion when the cut stub is through bleeding, and this may be an important factor some seasons as shown by L. H. McDaniels in work done at Cornell University and recorded in the September 1937, Report of Northern Nut Growers' Association.

The cleft-graft for large limbs and the whip-graft for very small limbs, as described in other sections of this bulletin, have proven best under Michigan conditions. The inlay-graft should be equally successful.

The best time for setting cions is when the new leaves are beginning to push out of the buds on the stock, sometime in early May.

Cions are best chosen from the base of large shoots of the previous season's growth so that it includes an inch of the two-year-old growth. Such cions seem to have more stored food material than does the pithy portion of the one-year-old growth. The best size of stock in which to set cions seems to be 1½-2½ inches in diameter.

It is thought advisable to coat the entire cion with the same material used to seal the union and end of the cion. Most propagators of nut trees tie a light-colored paper or cloth bag over the cion and stub and when very warm weather comes, the corners of the bag are cut open to allow ventilation while affording a few weeks of shade to the newly set cion.

In almost all other respects, the information given in this publication for propagating fruit trees will apply to nut trees.

INDEX

	PAGE
Approach-graft	50
Asphalt grafting compound	15
Bark-graft	29
Bridge-graft	44
Budding	36
Cleft-grafts, causes of failure	28
Cion tilting	27
Collar rot	41
Compatibility	20
Definitions	6, 7
Double-working	21
Fireblight	41
Grafting, time for	10, 35, 37, 46
Grafting tools	11
Grafting wax, functions of	13
Grafting wax: hand wax	14
Grafting wax: heater	13
Grafting wax: brush wax	14
Grafts, subsequent care of	38
Inlay method of repair grafting	48
Inlay method of topworking	30
Interstocks	6
Mouse-injury, prevention of	42
Nursery propagation	53
Nut tree propagation	54
Rabbit injury, prevention of	42
Repair grafting, varieties for	41
Stocks for fruit trees	53
Sunscald	19
Tongue- or whip-graft, method	35
Tongue- or whip-graft, causes of failure	36
Top working, success in	16
Top working, selection of branches to graft	17
Wounds, care of	42